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ABSTRACT

Issues related to the improvement of mathematics and science education pertain to Native students as well as to the general population. Native students are most successful at tasks that use visual and spatial abilities and that involve simultaneous processing. Instruction should build on Native students' strengths. Experiential learning and cooperative learning are two methods that are particularly effective with Native students in improving student attitudes and problem-solving abilities and reducing mathematics anxiety. Storytelling techniques can be used to develop culturally relevant problems. Career days show students the uses of mathematics in the real world. Curriculum development strategies include establishing the relationships and connections between mathematics and other subjects, and incorporating culturally relevant materials, such as Maya or Inca mathematics and science. Strategies of exemplary programs include summer math camps for Native students, summer institutes to improve teacher instructional skills and methods, after-school and summer enrichment activities in science and engineering, instructional materials developed to accompany a science series on public television, magnet schools, after-school college preparatory courses in mathematics, and parent resource centers. Recommendations are offered related to instructional methods, program development, and federal funding. This paper contains over 130 references. (SV)

Mathematics and Science Curricula in Elementary and Secondary Education for American Indian and Alaska Native Students

Vera Preston

Introduction

> Wake up, America! Your children are at risk. Three of every four Americans stop studying mathematics before completing career or job prerequisites. Most students leave school without sufficient preparation in mathematics to cope either with on-the-job demands for problem-solving or with college requirements for mathematical literacy... Since mathematics is the foundation of science and technology, it serves as a key to opportunity and careers. Moreover, mathematics contributes to literacy certain distinctive habits of mind that are of increasing importance to an informed citizenry in a technological age. ... Despite massive effort, relatively little is accomplished by remediation programs. No one — not educators, mathematicians, or researchers — knows how to reverse a consistent early pattern of low achievement and failure. Repetition rarely works; more often than not, it simply reinforces previous failure. The best time to learn mathematics is when it is first taught; the best way to teach mathematics is to teach it well the first time. (Everybody Counts, 1989, pp. 1-3, 13)

Testimony from the Indian Nations at Risk (INAR) Task Force meetings, regional hearings, and written testimony submitted to the INAR Task Force represents the diversity of Native peoples and the variety of schools attended by American Indian and Alaska Native students. The common thread existing throughout the extensive testimony is the need for American Indian and Alaska Native students to have their culture acknowledged and to be taught in the ways they learn. The type of school, the type of class (language arts, social studies, science, mathematics), the area of the country does not change the need to be respected as a human being and to be taught in a manner that allows the individual to understand and internalize the material to be learned. All children, regardless of race, gender, or ability, deserve to be taught in the ways they learn by building on their strengths and overcoming their weaknesses. Rather than emphasizing the differences, the message obtained from the testimony accentuates the common concern of Native people for educating their children. They want their children to be educated in a manner which enriches their horizons and guarantees a variety of options for lifelong learning and for various vocations.

For years reports have stated the need for reforming mathematics and science education in the United States. *A Nation at Risk* (National Commission on Excellence in Education 1983), *Educating Americans for the 21st Century* (National Science Board Commission on Precollege Education in Mathematics, Science and Technology 1983), and *Everybody Counts -A Report to the Nation on the Future of Mathematics Education* (National Research Council 1989) are representative of the reports concerning mathematics and science education. Compared to students throughout the world, students in the United States rank in ability with students from Third World countries. National Assessment of Educational Progress (NAEP) reports of results of 1986 assessments indicate that ability to answer problems requiring higher order thinking is lacking for most students in the United States (Brown, Carpenter, Kouba, Lindquist, Silver, and Swafford, 1988, pp. 241-248). Some reports have addressed the issue of what needs to be done to solve the problems. Claims of easy solutions to difficult problems should be viewed with great suspicion. Research indicates the way students learn is not always the way students are taught. Since teachers tend to teach the way they were taught and the way in which they learned, the vicious cycle of miseducation continues to handicap the lives of children of all ages, abilities, and races.

The National Council of Teachers of Mathematics (NCTM) has responded to the need for change in mathematics teaching by producing *Curriculum and Evaluation Standards for School Mathematics* (NCTM, 1989). It is a set of standards for mathematics curricula in kindergarten through high school developed by classroom teachers, supervisors, educational researchers, teacher educators, and university mathematicians working together. NCTM is very much aware of the

skepticism of people toward change after the "new math" of the sixties which imposed change from the top down. The current recommendations stress the importance of *all* students learning mathematics and the importance of revising mathematics instruction. The National Science Teachers of America (NSTA) has developed a Statement of Initiatives similar to the NCTM Standards. Emphasis is on more unified, in-depth hands-on science curricula for all students kindergarten through twelfth grade.

What can be done to improve the mathematics and science education of all children including American Indian and Alaska Native children? Why is mathematics and science education so important to all students? This paper will address the issues in mathematics and science education.

Mathematics and Science

Mathematics and science influence the lives of everyone. Scientific, mathematical, and technological literacy is crucially important for citizens to understand the technological world in which they live. Mathematics has been called "the queen and servant of the sciences." It is the study of patterns and relationships and is the foundation on which understanding of many fields of study is built. An understanding of mathematical concepts and mathematical reasoning is necessary in almost every occupation in today's technological society. Mathematics has been called a critical filter because so many occupations require a mathematical background. Many people perceive mathematics as an infinite set of meaningless rules which are impossible to memorize. Mathematics is constantly changing; more than half the mathematics known today has been developed since 1940. Science and mathematics are interdependent in our technological age. For example, understanding of environmental issues such as water availability and water pollution require an understanding of both mathematics and science.

Mathematics and Science Learning and Teaching

Fundamental change in the way mathematics and science is taught is necessary (NCTM Standards, 1989; Willoughby, 1990). Information from mathematics and science educational research and from cognitive psychologists should be used to develop plans for organizing instruction for mathematics and science classes. Research indicates American Indian and Alaska Native students are most successful at tasks which use visual and spatial abilities. (More, 1986) Many students, including Native students, use holistic, global processing of knowledge which enables them to perceive various elements as a whole. Seeing the whole picture, a holistic, global process is referred to as simultaneous processing. Processing information sequentially and in an analytical manner is referred to as successive processing. (Das, Kirby, & Jarman, 1975. Quoted in More, 1986, pp. 8-9) Research results indicate Native students use simultaneous processing more frequently and effectively than successive processing. It also indicates that Native children are more field independent (FI) than field dependent (FD) and that they tend to think in relational styles rather than in analytic styles. (More, 1986, pp. 9, 12) Research on culturally based communication styles related to the classroom has been done by Scollon and Scollon (1983) and Phillips (1972). Studies of teacher effectiveness which relate to styles of communication of Native Indian students have been done by Kleinfeld (1970). Traditional Native cultures teach children to watch, listen, think and then do the task to be learned. Many classrooms encourage trial-and -error learning. Many students become quite proficient at guessing until they get the correct answer. Trial-and-error learning is the antithesis of traditional Native learning styles.

> Field independence is the degree to which an individual can separate a figure from its background, a part from the whole. oneself from the environment or other people. A field independent (FI) person is more able to provide an organizational structure to a disorganized set of facts or observations (e.g., making a mental map of the surrounding terrain). A field dependent (FD) person is less able to separate a part of the whole, but is more conscious of other people... . The FI person will impose his or her own structure on a field (spatial or conceptual) more readily. The FD person is more socially aware and more responsive to those around him or her. (More, 1986. pp. 10-11).

There is considerable overlap between the learning styles of Indian and Non-Indian students. Indeed the similarities are probably greater than the differences. Furthermore, it is likely that the learning styles of some groups of Non-Indians will be remarkably similar to those of Native Indians. This could occur when there are similar factors affecting the way of life such as degree of remoteness of the community, economic level, and significant cultural differences from the majority. However in such situations cultural differences should not be downplayed. Even though the pattern of learning styles is similar, the causes and the methods of work-

ing with the learning styles may not be." (More, 1986, p. 20)

It is important to realize that teaching styles that are appropriate for Native students are also appropriate for other students. Methods of teaching found in many schools are not appropriate to the ways children learn. This is one of the major reasons for the need of remedial classes. If students were taught concepts in the way they learn, the need for remedial classes would be greatly diminished. Since Native students have strengths in using visual/spatial/perceptual information, new material should be introduced using methods building on their strengths. The overall view of new information should be stated before the information is broken down into small segments. Advance organizers should be used. Students' strengths should be used to develop skills in other modes of learning. (More, 1986, p. 21) Students should have the right to learn beginning material in their native language to allow them to develop a cognitive base on which to learn for the remainder of their lives. (McDonald, 1989, p. 16)

Children are born with a love of learning and an innate curiosity. The first three years of life a child learns a tremendous amount of information. Parents are the first and most important teachers of a child. How can a child's natural desire to learn about his/her surroundings be nurtured and maintained in academic situations? How can students learn the necessary material in the various classes? Many theories exist regarding how people learn. There is danger in stating that a specific group of individuals learn in a particular way. It is important to be sensitive to the needs of each individual and help that individual build on her/his strengths and increase ability in areas of weakness. (More, 1986) Many people have a preferred learning style. Many researchers stress that students should be allowed to learn from their strengths. Research in mathematics anxiety indicates that students overcome their anxiety and are able to perform better in mathematics if they build success on success. (Tobias, 1978)

Manipulative, hands-on, Materials

"Tell me, and I forget; Show me, and I remember; Involve me, and I understand." Ancient Chinese Saying.

Students who use hands-on materials, otherwise known as manipulatives, have better attitudes toward mathematics and better ability to problem solve (Suydam and Weaver,1975; Trafton,1975). Students who use manipulatives and are guided to bridge the gap from concrete to pictorial to symbolic representations are better able to understand concepts and to transfer their learning to other situations (Suydam,1986). Teacher guidance is important in bridging the gaps from the concrete to the pictorial to the symbolic stage. (Kouba et al., 1988b) Educators from the early part of the century to the present have advocated the use of physical, or concrete, materials in the classroom. (Brownell, 1935; Burns,1986; Montessori,1965; Piaget,1952; Reys,1971; Suydam,1986) Recommendations from reports of the most recent NAEP results encourage the use of concrete materials and activities. NCTM has recommended the use of physical, concrete materials in the classroom. (NCTM 1980; NCTM 1987) *An Agenda for Action: Recommendations for School Mathematics of the 1980s* (NCTM, 1980, p. 12) includes the following: "Teachers should use diverse instructional strategies, materials, and resources, such as ... the use of manipulatives, where suited, to illustrate or develop a concept or skill."

There are many benefits which occur as a result of using manipulatives. Mathematics anxiety is almost non-existent in classes where manipulatives are used frequently. The attitude toward learning mathematics is consistently more positive as a result of using manipulatives and of participating in cooperative learning. Student understanding of concepts is greater among all ability levels. Parental involvement is easier to obtain by having some activities done at home using common household materials. Students need guidance with the teacher as facilitator on the use of the manipulatives. Assistance and guidance in understanding the concepts represented by the manipulatives and in bridging activities to go from the concrete to the pictorial to the symbolic or abstract are essential in using the materials to best advantage (Heddens,1986). Learning what to do and why enables students to retain information and transfer the learning to other situations (Burns,1986). Fuson (1981) writes that there is a meta-cognitive benefit in the use of concrete objects. Teachers' sensitivity to styles of learning will help their students. A balanced view of various methods of teaching and learning will assist students to recognize their particular style of learning. (More, 1986) The teaching/learning style is determined by the learning task. Learning how to learn and recognizing the underlying concepts and features of mathematical problems is very important.

Cooperative Learning

Current issues in educational circles include teaching thinking through the curriculum, problem solving, cooperative learning, writing across the curriculum, and learning how to learn

(Simon,1986). Cooperative, or group, learning is being recognized as important in learning concepts. Since people work cooperatively in most situations outside school, students should have opportunities to work together in school. The many benefits which occur as a result of cooperative learning are an ability to communicate verbally the information and concepts being studied, an understanding of other peoples' attitudes, a positive attitude toward learning, recognizing there are various paths to the solution, and clarifying one's own understanding. (Slavin, 1987)

Cooperative learning is a popular concept at the moment in education. The merits and disadvantages of cooperative learning are discussed in four articles in the February 1991 issue of Educational Leadership (Kohn, 1991; Slavin, 1991). It is important to note that cooperative learning has been used successfully by teachers over the years without the label of "cooperative learning." Much of the discussion in the articles relates to giving rewards for group effort. Rather than getting bogged down in semantics or side issues, teachers need to consider the advantages of cooperative learning and apply the concept as appropriate to their particular situation in their specific classroom. Teachers must acknowledge that cooperation in the world outside the classroom is expected and necessary for success in projects throughout the business world. Mathematics and science learning should involve learners working together. Mathematicians and scientists talk to each other and try new ideas and check each other's reasoning. They do not work in total isolation. Research overwhelming supports the concept of cooperative learning and working together. It is particularly appropriate to the learning style of many Native students. There are many different forms of cooperative learning. The most successful approaches have incorporated group goals and individual accountability (Slavin 1991). Many of the advantages of cooperative learning are social as well as academic. Mathematics anxiety is practically non-existent when students are allowed to work together to discuss and learn new information.

Many teachers used cooperative learning before it was called cooperative learning. Students worked together and helped one another and recorded the results of their experimentation, their searching for patterns, or their explanation of new definitions, concepts and material. Each group turned in one paper with their results. Students were each responsible for the material and wrote individual reports later. The method of having students work together was successful with students in gifted classes and in remedial classes at all levels.

Storytelling and Problem Solving in Mathematics and Science.

Storytelling as a means of teaching is traditionally used by American Indians and Alaska Natives. Using stories to pose mathematical or scientific problems is a natural way to relate situations of the student's home life and culture within the mathematics classroom. Students arrive in school with the ability to solve problems which have meaning for them. School textbooks and mathematics lessons frequently convince students they are unable to solve the problems which had previously been easy for them. One of the important skills in solving problems is drawing pictures representing the problem. (Davis & McKillip, 1980, pp. 80-91)

An ancient example of using storytelling to pose a mathematical problem is the story of the person going to St. Ives. "As I was going to St. Ives, I met a man with seven wives. Each wife had seven cats, each cat had seven kits. How many were going to St. Ives?" Only one person was going to St. Ives; the others were leaving St. Ives. The problem involves listening and reasoning. The mathematics involved is rather straightforward.

Students enjoy making up story problems when the teacher provides an encouraging, accepting, respectful atmosphere in the classroom. The entire family could participate in posing story problems which incorporate mathematical and scientific problems. For example each of the following mathematical type of questions could be posed in a story. How much flour is used for making fry bread? How does the volume of the fry bread change when it is cooked? When popcorn is popped, how much does the volume change? How many seeds are there in a watermelon? What are some strategies for determining how many seeds are in the watermelon? What are the differences in types of seeds? What are the shapes of leaves? How many leaves are on the plant? How many steps does each person in the family take for walking the same distance? (What is the stride of each person?) How many sheep per acre can the land support without irrigation? How many cattle per acre can the land support? How many bales of hay can be put in a pickup? What is the most efficient shape to build a house if materials are scarce? (A circle is the most efficient shape to provide the most area for the same amount of fencing. A square is the most efficient straight-sided figure. Why?) How many days did it rain last week, last month, last year, ten years ago?

What is the difference in temperature from 5:00 AM to 5:00 PM on the same day?

Mathematics Anxiety

Many students develop a fear of mathematics during the elementary, middle school, junior high years which cripples their ability to learn mathematics in high school and later. Other students do well in mathematics classes until they reach algebra or geometry. When they have difficulty in mathematics, they quit taking elective mathematics classes. They take the path of least resistance when taking required mathematics classes. It is important for students to be encouraged, possibly required to take mathematics classes each year of high school. Students must realize that mathematics is a critical filter. The more mathematics a student studies, the higher the expected lifetime earnings, and the more opportunities for employment are available. Students can choose a job or career based on what they enjoy doing rather than on what requires no mathematics. Counselors should be required to insist that students stay in mathematics classes rather than allowing them to drop out when the going gets tough.

Mathematics anxiety and test anxiety is usually found in students after the elementary school years. When students are asked to relate their experiences leading to mathematics anxiety they usually relate it to something which occurred in elementary school. Reasons students at the community college level give for their mathematics anxiety include moving a lot during elementary school, family problems, receiving beatings from a parent when multiplication facts were not learned fast enough, getting behind when ill and never catching up, being told they were not smart enough to do mathematics, and getting behind in mathematics because they did not understand a particular concept. Many students who had difficulty with mathematics in elementary school have learned they have a learning disability. With persistence and determination many students with learning disabilities are successful in mathematics classes.

Acknowledging mathematics anxiety and suggesting ways to overcome it helps students. Students can be given a list of books which discuss mathematics and test anxiety and how to deal with it. The most effective way for a student to overcome mathematics anxiety is to have opportunities to be successful in solving mathematical problems. (Langbort, 1985; Tobias, 1978) Many activities for discovering patterns and for solving logic problems improve attitudes toward mathematics. There are many books available which provide interesting mathematics and science activities for students of all ages.

Career Education

Career days for elementary, middle, and junior high school students enable the students to learn about different types of careers. Native students should be encouraged to consider careers in fields which will help their communities. Careers in health fields, environmental science, agricultural science, various type of engineering, attorneys, counselors, and business all have the potential for helping their communities. Expanding Your Horizons Workshops and Career Days were originally organized for females. The format is appropriate for American Indian and Alaska Native children. Students should be encouraged to continue their education so they will be prepared to help their community in many ways.

Students generally lose their innate enthusiasm for science and mathematics during the crucial junior high years. Therefore, it is critically important to provide elementary, middle, and junior high school students opportunities to experience challenging and interesting projects and programs in mathematics and science. It is also critically important for students to recognize that mathematics is a critical filter for many interesting and exciting careers. Most professions require college mathematics courses through calculus. Most students who are successful in their college mathematics classes took a mathematics class their senior year in high school and then took a college mathematics class their first semester in college. When mathematics classes are taken consecutively they are much easier than when a number of semesters have gone by between classes.

After-school, weekend, and summer programs provide fun, interesting, challenging opportunities for students to learn about mathematics and science. Programs which emphasize hands-on experiences, applications to real life situations, and field trips are particularly successful in encouraging students to consider mathematics and science oriented careers. It is important to take advantage of resources within a community when planning programs. Many people are willing to share information about their career when they are given the opportunity to do so.

Environmentalists are just realizing what Natives have known for centuries. Careers which relate to environmental issues are important for people throughout the world. Native students should be informed of the opportunities to help their communities by studying various fields of science related to preserving and maintaining the environment. Water pollution, toxic waste, agricul-

tural and industrial chemicals are some of the topics which can be addressed. The wise use of technology can best be monitored by people who understand the technology.

Medical personnel are needed in rural areas and small towns throughout the United States. Native people need to encourage their children to consider pursuing a career in one of the many health related professions. Dieticians, nurses, radiology technicians, physical therapists, occupational therapists, family physicians, and physicians who are specialists are some of the health related professions students can consider.

Each area where Natives live have specific needs regarding the environment and the economic and business situations. People are needed who have the vision to develop small businesses to meet the needs of the area. Attorneys are needed to provide necessary information and ex pertise for protecting the interests of the people. Biomedical engineers, chemical engineers, civil engineers, electrical engineers, biological engineers, and other engineers are needed to protect the environment and help the community. Leaders with vision who are aware of long-term needs of the Native community are needed. Educators with sensitivity, ability, and knowledge of subject matter are needed to provide role models for the children. Our children are precious. They are the future.

Parents and other members of the extended family have a tremendous influence on children. Encouragement and belief in a child's ability to persevere through the challenging times on the path to a career that will be fulfilling to the individual and will provide the opportunity to enrich and help the community are crucially important. Many students state that the reason they stayed in school was because someone believed in them and encouraged them when they were discouraged.

An activity which helps middle school students discover the importance of mathematics in careers is "mathenger hunt," based on a scavenger-hunt idea. Teams of students are selected by the teacher. Students gather a minimum of twenty signatures from people who state they use mathematics in their career. The class decides on a point system. Additional points can be earned by obtaining additional evidence from the people related to their use of mathematics. Some side effects of the project were offers by people to speak to the class, scrapbooks of the signatures and other information were shared with other classes, and the class compiled word problems relating to careers (Falba & Weiss, 1991, pp. 88-90).

Instructional methods that motivate Native students, challenge their minds, stimulate their creativity and initiative.

The diversity of Native peoples provides tremendous opportunity for developing materials for mathematics and science classes which can be shared with schools throughout the country. A vision where all children are given the opportunity to share in the joy of holistic lifelong learning is shared by people from all walks of life and from many races. There is beauty in learning and recognizing that all of life is interrelated. One day that vision will come true when all work together for the children. People throughout the country should demand that students be taught in ways which build on their learning strengths. Students, regardless of their ability level, learn new concepts from the concrete (hands-on) to the pictorial to the abstract (Piaget, 1952; Brownell, 1935). Activities are needed to bridge the gap from the pictorial to the abstract and need to be included in the learning activities.

Learning is fun. Math is fun. Science is fun. Teaching needs to stimulate children's natural curiosity. Teachers do not necessarily have to reinvent the wheel. They can adapt material to make it appropriate for the area in which students live. There are many materials available which provide challenging, enriching, and relevant experiences in mathematics and in science. Using manipulatives throughout the school years as new concepts are introduced will stimulate interest and assist understanding. When materials are provided in a mathematics laboratory type of situation, students enjoy solving problems posed using various materials. Consider the following example. When an apple is cut crosswise, a star is formed. Students can be asked how many points does the star have? How many seeds are there? Why is a star formed? How was the apple formed on the tree? In what soil and weather conditions do apples grow? How many types of apples are there? Which type of apples make the best juice, pie, snacks? What chemical is found in apples that is calming for people?

In-service training is helpful for teachers to learn to use new manipulatives and other new materials. There are various programs available for providing elementary teachers with experience in using mathematics and science materials. Some programs teach specific mathematics and science classes. Some programs combine both aspects. *Open Math* is a resource book for a set of videos, originally television programs, developed at Arizona State University by Jonathan Knaupp and

Gary Knaniller. Teachers can watch a video each week and try one new activity. The following week they can share their successes and their failures and learn from one another. Little by little they expand their repertoire of instructional methods.

Change occurs slowly in education. For change to occur in the way children are taught, teachers must be provided opportunities to learn how to use new methods of teaching. A one-day workshop is not sufficient to help a teacher change the way in which she/he teaches. Summer school classes or workshops combined with regularly scheduled in-service during the academic year is a way in which to effect change. It is difficult, frustrating, and slightly frightening to change teaching methods. Teachers need encouragement and support to change the way they teach. An example of the type of person who can inspire others to do their best is Dr. Helen Neely Cheek. Dr. Cheek was a wonderful, inspiring teacher and educator who taught elementary and secondary teachers new methods of teaching. She provided opportunities to learn new methods of instruction little by little until each teacher was comfortable using new materials and new methods of instruction. She emphasized recognizing each student's strengths and weaknesses and building on their strengths to overcome their weaknesses. (Preston & Skinner, 1986)

Curriculum Development Strategies

Mathematical Connections is standard four of the NCTM Standards for kindergarten through high school. Relationships between mathematical topics and other curriculum areas are encouraged. "Unless connections are made, children will see mathematics as a collection of isolated topics" (NCTM Standards, 1989, p. 33).

Mathematics as Communication is Standard Two of the NCTM Standards. Students need to be able to clarify their thinking to fully understand mathematical concepts. Communication by representing concepts using manipulatives, by using diagrams and drawings, by discussing ideas, by listening, by reading, and by writing are all important. Knowledge must be able to be communicated to others before its usefulness and applicability can be determined and utilized.

Culturally relevant mathematics and science materials address both of the above-mentioned standards. Geometric designs found in all Native cultures can be used to develop geometric and algebraic understanding. Art can be used to develop concepts of estimation to know the amount of paint, clay, beads, etc. which are needed for the project. Chemistry and mathematics can be used to obtain the colors needed for art projects. Geometry is used to develop perspective in many paintings (Serra, 1989). When mathematics and science units are developed using the interests of the students, motivation and enthusiasm for learning are increased. Tesselations, Pascal's Triangle, and the Fibonacci Sequence are topics which relate easily to Native mathematics and science lessons. Tesselations, otherwise known as tilings, can be created using Native designs. Pascal's Triangle can be used to develop algebraic, probability, and network concepts, and to create patterns, artwork, and beadwork designs. The Fibonacci Sequence can be used to study botany, architecture, art, and packaging and marketing topics in advertising. It can be included in a study of medieval times since Fibonacci lived in the thirteenth century. (Preston, 1985)

Linda Skinner has developed a week-long process where teachers, paraprofessionals, Elders, parents, students, and other community members collectively experience various aspects of culture. From their experiences and unique perspectives they create and develop culturally relevant learning activities and materials. They return to their individual communities with renewed enthusiasm strengthened by the focused energy on the common goal of creating the best education experiences for the children of their communities.

Mayan and Inca Science and Mathematics

Examples of culturally relevant mathematics material related to other disciplines are Mayan Mathematics and Inca Mathematics. A unit on Mayan Mathematics or on Inca Mathematics can be developed to include geography, social studies, astronomy, archaeology, agricultural methods, development of corn, development of potatoes, art, glyph translations, architecture, language arts, music, physical education, probability, acoustical engineering, civil engineering, textiles, minerals. Various topics could be studied in different grade levels.

Mayan mathematics was highly developed. The concept of zero was recognized by Mayans long before it was recognized in European mathematics. A concept of zero is necessary before a mathematical system can have a place value system. It al-

lowed Mayans to think about and write numbers that were very large. They had two separate but related mathematical systems. One was a vigesimal, base twenty system, used to count things and the other was an adjusted base twenty system used to count time. Only three symbols were used to represent all their numbers, a dot to represent one, a bar to represent five, and a cacao bean to represent zero. (Most references state that the symbol for zero is a type of shell. Patrick Scott, University of New Mexico, has been working with Mayans in Guatemala who believe the symbol was a cacao bean.)

"The Mayas thought of time as a never-ending flow into the future and back into the past. They believed that history repeated itself when conditions were exactly as they had been in the past. For this reason, it was extremely important that the priests continually study prevailing conditions in order to compare them with past conditions" (Callahan, 1969). Charles H. Smiley, Professor of Astronomy, Brown University, Providence, Rhode Island, in conversations with the author, claimed to have predicted a hurricane for the New England coast using information from the Mayan Dresden Codex, one of the remaining books of the Maya. He boarded up his house on the coast and had no damage.

Mayans were able to construct temples, pyramids, and ball courts with admirable precision. Acoustics allowed priests to whisper and be heard across the plaza. Astronomical observatories allowed them to observe and accurately record information regarding planets, comets, and stars. As communication with Chinese mathematicians and astronomers increases, astronomical information for studying the correlation of Mayan dates with current knowledge of historical dates improves. Agricultural accomplishments of the Mayas include development of many crops we use today. Raised fields were used in swampy areas and water reservoirs were established in dry areas.

The Incas of South America were great organizers. Their highway system was more extensive than the Roman highway system that is recognized in history books. Parts of the Inca highway system are still used. Irrigation methods used terracing for maximum use of water. Throughout Peru there are Inca terraces on the sides of mountains that are still used. Surgeons were able to perform delicate, successful brain surgery. They had an extensive knowledge of herbal medicine. The weaving with feathers and gold thread cannot be duplicated today. The artistry using gold is unmatched with today's knowledge of technology. It is still a mystery how the structures of the Incas were built without the use of wheels to transport the gigantic stones and without mortar between the stones. After centuries of earthquakes, many of the Inca structures remain intact while modern structures are destroyed in recent earthquakes.

Exemplary Schools, Programs, and Projects

The Colorado School of Mines in Golden, Colorado, has held summer math camps for American Indian and Alaska Native middle school students since 1988. The first one was held in conjunction with the American Indian Science and Engineering Society (AISES) and was funded by the Educational Foundation of America. Dr. Barbara Bath is the director and Dr. Ardel Boes, head of the mathematics department, is the administrator of the math camp each summer. The purpose is to expose Native students to mathematics in various ways and provide opportunities to learn about various mathematics and science oriented careers. One of the major goals is to develop or reinforce positive attitudes toward mathematics. Results from pre and post tests of attitude and cognitive reasoning indicate improvement is fairly consistent for all the students. The type of mathematics studied helps students in their regular math classes during the year. Activities in the mathematics classes emphasize patterns, logical thinking, and spatial relations. Hands-on, manipulative activities are used extensively. For example, pattern blocks are used to make designs and patterns in the mathematics classes. The designs can be duplicated using the computer. Computer classes include developing tesselations and other geometric designs. Logo is used because of its problem solving capabilities for students. Since the second year mathematicians and computer scientists from Bell Laboratories of AT&T have volunteered to be mentors to assist the students in their projects. Students' informal evaluations state one of the benefits of the math camp is learning to deal with new situations and adjust to them. Parents contacted Dr. Bath and informed her that their child's attitude toward school, achievement in school, and self-concept had improved after attending the math camp.

The second year a student program and a teacher education program was funded by the Department of Education. A Middle School Teacher Enhancement Geometry Program was funded by the National Science Foundation (NSF). A Young Scholars Program and a Middle School Teachers Algebra program was funded by NSF the third year. The summer of 1991 another Young Scholars Program and Middle School Teachers

program will be funded by NSF. The program has been designated a Program of Excellence by the Colorado Commission for Higher Education and has received five years of funding for the Middle School American Indian and Alaska Native Math Camp and the Teacher Education program.

The University of Kansas, Haskell Indian Junior College, and the Bureau of Indian Affairs together developed and presented two eight-week mathematics and science elementary teacher institutes in the summers of 1988 and 1989 funded by the National Science Foundation. Funding has been allocated by the National Science Foundation for the summers of 1991 through 1993. The Mathematics and Science Teachers for Reservation Schools (MASTERS) Project focuses on improving classroom instruction skills of teachers. Three themes are emphasized: students' concrete firsthand (hands-on) experience with the concept being taught; cultural relevancy of the curriculum objectives, materials, and teaching technique, and positive role models and community involvement in instruction.

Science is studied using hands-on experiences. Air and space topics are a focus of many of the activities. Science and mathematics activities are related to all aspects of life using a whole language approach. Biographical information about Native American scientists has been compiled. Science and mathematics activities related to the biographical information will be developed in future workshops. The vision of the program is to develop mathematics and science activities within all aspects of the curriculum. During the summer of 1991 there will be thirty-five new students and twelve returning students. MASTERS' goals include improving mathematics and science instruction at the individual teacher level, within the schools of the participating teachers, and within the overall system of reservation schools.

> "Change is not a quick process; and change agents are not made overnight. MASTERS' goal is to produce a core of skilled mathematics and science teacher leaders who can work with their fellow faculty and community, not impose improved science and mathematics teaching programs." (Smith, W.S., 1990, pp. 1-2)

National Action Council for Minorities in Engineering, Inc. (NACME) launched TechForce 2001, a program for students who will be earning engineering degrees at the beginning of the new century, in 1989. NACME, the South Dakota School of Mines and Technology, AISES, and the local school districts in Rapid City and Kyle formed a coalition to provide a Scientific Knowledge for Indian Learning and Leadership (SKILL) program. Students in five elementary schools in Rapid City and Kyle will participate in after-school academic year and in summer enrichment activities. Students will study science and engineering as they relate to their everyday lives. Science Made Simple is a two week non-residential summer camp. Since NACME requires community partnership and matching funds, Amoco, the South Dakota Community Foundation, U. S. West Communications, and Title II (United States Department of Education) now help support the program. (Campbell, G. Jr., 1990)

Porter Middle School in Austin, Texas, has a very innovative science teacher, Sharon Mitchell. She is the adviser of the Earthnauts, a group started "by kids for kids." The students work in a biodome to test theories of growing food without pesticides or without otherwise harming the earth. They grow vegetables in water instead of soil. The group has published a book of poetry, written a proposal to NASA to gather ground-level data to help the agency fine-tune readings from orbiting satellites, and produced a series of comic books about the environment for elementary students. Students are in charge of the biodome and the plants grown there. Involvement in Earthnauts has caused many students to plan to go into various branches of science. (Smith, S., 1990, pp. B1, B4)

The New Jersey Institute of Technology sponsored an Experimental Mathematical Science and Communications (EMSAC) program for seventh grade students during the summers of 1983 and 1984. The 1984 program focused on mapping and surveying, observational astronomy, Apple Logo, communications, and probability and statistics. The program was for inner-city students. NCTM's 1981 Yearbook, Teaching Statistics and Probability, was used to develop the probability and statistics concepts introduced. Students played coin toss games and games using dice. Games were determined to be fair or unfair by playing the games and keeping results. After discussions of results of the games, students determined which games were fair or unfair. A Casino Day was held to study the concept of determining odds. One of the learning objectives was to have students realize that there is at least one best strategy for playing each game. After Casino Day the games with obvious strategies were discussed. Pascal's triangle was used to help explain the odds. Geometric probability was introduced by discussing variations of the Lady or the Tiger game. Determining the winnings when a game ends prematurely while a person is ahead was studied. Monte Carlo techniques and simulations were used to discuss prizes in boxes of cookies. Student

interest was highest when there was active participation. Students enjoyed playing games, tossing coins, and other activities to help them understand probability and statistics. (Scheinok, 1988, pp. 310-314).

St. Paul, Minnesota, School District is developing an American Indian Magnet School for grades K-8. The 1990 school year is for planning. The opening is scheduled for the 1991-92 school year. The priorities are to provide the opportunity for optimum learning for each student and to help each student recognize her/his self-worth. Hands-on approaches and laboratory work will be used to teach mathematics and science. The University of Minnesota's National Science Foundation Project will work closely with the school. Early Childhood/Family Education Programs will be available for the entire range of situations from expectant parents up to families of high school students. A parent resource center will be available for parenting groups; it will offer activities to strengthen families.

Chicago area teachers and scientists have developed instructional materials to go with each of the thirteen episodes of a new Public Broadcasting System series "The New Explorers." The scientists in the series include an ethnobotanist, an astronomer, a zoologist, a surgeon, a chemist, an ornithologist, a microscopist, environmental scientists, and computer scientists. One of the results of developing the materials is teachers getting to know the scientists. Students are able to visit scientists to learn more about where scientists work and what they like about their jobs. For information about the project and the teachers' guides, write to the Chicago Science Explorers Program, Division of Educational Programs, Argonne National Laboratory, 9700 S. Cass Ave., Argonne, IL 60439-4845. (Koepke, 1991, pp. 50-55)

Boothbay Harbor and Wiscasset, Maine teachers and scientists are working together in a kindergarten through twelfth grade interdisciplinary program where students are developing maps of the area. The students use computers to interpret information from Frances's SPOT satellite to create highly detailed maps of their area. The project, called the GAIA Crossroads Project, received technical support from an Apple Computer Crossroads Education Grant. (Wolcott, 1991)

The Houston Independent School District and Baylor College of Medicine in Houston collaborated to develop the Mathematics/Science/Computer Center at Fondren Middle School in the fall of 1987. It exists as a special population within the school. There are now classes for sixth through eighth grades. Multidisciplinary units relate all subjects together. Units developed include: Space Frontiers, Mammals, Preservation of the Earth, Perception/Sense Organs, Chemistry of Life, Weather, Origins of People, Topology, Prejudice, Ecology, Astronomy, Research, Topography, Architecture, and Music. Parents are involved and kept informed by attending an open house at the beginning of the year, by receiving newsletters, and by attending a science night. A week-long summer science camp for magnet students was sponsored by Baylor in 1988 and 1989. (Miller, LaVois, and Thomson, 1991)

Mercer Island, Washington, High School has an innovative physics teacher, Jim Minstrell. He uses research on how students learn and how to counteract the preconceptions with which they enter physics classes in planning his classes. He received a grant to research how students learn. "The project has three closely related goals: to identify in more detail students' preconceptions about the physical world; to explore ways teachers can use those preconceptions to teach physical laws; and to prepare classroom materials that other teachers can use to teach physics (Wolcott, 1991)."

Professional Development Program (PDP) of the University of California at Berkeley has developed a PDP High School Mathematics Workshop Model to encourage more minority students to do well in college-preparatory mathematics courses. The workshops are held at the high schools before or after school twice a week throughout the school year. Consistent attendance is required; it is not a "drop-in" program. The workshops are designed to supplement specific courses rather than to remediate. Difficult and nonroutine problems are included in the problem sets used. Workshops are led by college students who are majoring in mathematics, science, or engineering. For information contact Uri Treisman, PDP Program, 230B Stephens Hall, University of California, Berkeley, CA 94720. (Stanley, 1991)

The American Association for the Advancement of Science (AAAS) is sponsoring Project 2061, a long-range, multiphase project to determine what scientific literacy should be and how to accomplish it. Project 2061 published *Science for All Americans* in 1989. The AAAS project "Linkages to the Future" is assisting local Girl Scout councils in developing hands-on activities and increasing connections between scientists, engineers, and scientific organizations in the local areas. Making Mathematics and Science Work for Hispanics is another AAAS program. For information contact AAAS, 1333 H Street, N. W., Washington, DC 20005. (Reeves, 1991)

Various programs could be used for Native students with slight or no modifications. Some programs to consider in addition to previously mentioned programs follow. Information regarding Math/Science Network, Family Math, Family Science, Math for Girls and Other Problem Solvers, How to Encourage Girls in Math and Science, and Expanding Your Horizons Workshops is available from the Lawrence Hall of Science, University of California-Berkeley, Berkeley, California 94720. *Futures* with Jaime Escalante is a mathematics and science series created by the Public Broadcasting Service, 1320 Braddock Place, Alexandria, VA 22314-1698. Phillips Petroleum Company, Bartlesville, Oklahoma, 74005, has sponsored two series of mathematics and science videos, Challenge of the Unknown (mathematics) and Search for Solutions (science). The videos are available for rent free of charge. Teacher guides have been developed to go with each video.

Recommendations

Mathematics is a "critical filter" which provides opportunities to pursue interests in many different fields of study. Native students must receive a solid foundation in mathematics in order to have options available to them. Mathematics and science must be taught in the way children learn — from the concrete to the pictorial to the abstract. Mathematics and science should be taught in an experiential manner. Activities should include experiments and the use of hands-on materials. Mathematicians and scientists in the real world work together and use models to demonstrate their ideas. Students should be expected to use hands-on materials at all levels, kindergarten through the twelfth grade, to demonstrate their ideas. Students should work together in groups in various types of activities. Mathematics and science should be taught in interdisciplinary units which include language arts, social studies, physical education, art and music — all aspects of the curriculum.

Computers, calculators, and graphing calculators should be used within the science and mathematics classes. The use of calculators and computers allows students to study problem solving using higher level thinking skills. Students must be instructed in the use of current technology to prepare themselves to live in a technological age.

Culturally relevant materials should be used to teach mathematics and science. Materials are available and other materials can be developed. A national clearinghouse or computer network should be established to assist teachers and parents in determining what materials are presently available. Mathematics and science are naturally related to the lives of Native students.

A core curriculum at the elementary and secondary levels that challenges all students and prepares them for the next stages in their education should be provided. Schools and school systems should use the NCTM Standards to set specific goals for student mathematics' learning. These goals should be used to develop culturally relevant multidisciplinary units for kindergarten through the eighth grade. At the junior high and senior high level, mathematics and science teachers should communicate with teachers of other disciplines to coordinate some topics. High schools must ensure that graduates are prepared to continue into post-secondary education with the expected skills in reading, writing, speaking/listening, mathematics, reasoning and studying. Schools should not steer or "track" Native students into vocational or general curriculum in ways that preclude solid academic preparation necessary to pursue a college education.

Native children should be expected to succeed! Make sure that this expectation of success is shared by students, parents, teachers, and administrators. Schools and school districts should make the educational process more familiar to Native parents by holding school meetings in the communities or by meeting with parents regularly to review their children's progress. Money, time, and effort should be invested in pre-school and elementary school programs to provide a solid foundation of learning and self-esteem for the children. When mathematics and science are taught in ways students learn there will be no need for remedial instruction. All children can learn! Summer programs for junior high and middle school students are very important in determining their classes for high school. Encourage and sponsor students to attend pre-college summer enrichment programs in mathematics, science, and health science. Provide opportunities for students to learn about careers and opportunities in mathematics, science, and health fields.

Establish programs which identify gifted Native students early in their school careers. Provide enriched and accelerated programs, credit by examination, and other special arrangements to ensure that these Native students are appropriately challenged rather than lost in the system. Independent learning should be encouraged. Parents of gifted students should encourage their children to be self-motivated and to study independently their own area of interest. Help them find information or write for references and material about their interests.

Education needs to be more holistic to achieve a joy of learning which will lead to life-long learning. Parents and community leaders should insist that children be taught in the way they learn. Parents and community leaders should insist upon the purchase of hands-on materials to be used in the classrooms and instruction of faculty in the use of same. Insist that teachers new to the system attend in-service training which sensitizes them to the Native culture of the area and the special needs of the Native children in that particular school. Native parents, grandparents, and relatives need to recognize the importance of motivating their children to finish school and to help them succeed in the educational process.

The Federal government must maintain the national commitment made to the Native people. Improvement of the current situation requires commitment of time and money. ACTION is needed NOW. President Bush and the governors have stated goals for education but have not appropriated funds to meet those goals. Words with no action are meaningless. Inaction approaches criminal negligence of our children who are our future! Money is better spent on education that is effective and relevant now rather than on remedial programs and criminal justice programs later. Funds are required to make salaries competitive and to provide continuous training for administrators, faculty, and staff regarding learning styles, instructional methods, including the use of hands-on (manipulative) materials and the use of culturally relevant material. Funds should be available to pay for administrators and faculty to attend conferences, summer institutes, and other classes to maintain current knowledge of activities and research in their field. Funds are required to develop culturally relevant curricula within the previously determined curricula. Funds are required to provide hands-on materials and consumable materials for science and mathematics classes, kindergarten through twelfth grade, in a manner similar to the way in which materials are provided for art classes. Funds are required to improve existing facilities, or build new facilities, which adhere to federal guidelines for the safety of all students and which provide accessibility for the handicapped. It should be noted that excellent facilities just by their existence do not produce innovative, effective instructional methods. The facilities provide an environment conducive for learning and teaching. If funds are spent only on structural renovations of the school and not on teacher support programs, teacher training, and classroom materials, then the money has been wasted. The entire situation needs to be considered as a whole not in isolated parts. Time is required to accomplish the changes necessary. Nevertheless, ACTION is required immediately. The children are watching us to determine by our actions how important education is to us? What are they seeing?

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About the Author

Vera Preston grew up in Stillwater, Oklahoma. Her BS in Education is from Oklahoma State University; her MA in mathematics is from the University of Maine-Orono. Her thesis was *Mathematics in the Aztec, Mayan, and Inca Cultures* (written as V.P. Callahan). She was a doctoral student of Dr. Helen Cheek, a Choctaw educator, at Oklahoma State University. She is completing her doctoral work at the University of Texas at Austin with Dr. Charles Lamb.

She teaches mathematics at Austin Community College (ACC) in Austin, Texas, where she has developed a "Building Success in Mathematics" course. She develops culturally relevant American Indian and Alaska Native mathematics materials. She developed and taught the mathematics curriculum for the American Indian and Alaska Native Math Camp at the Colorado School of Mines the summer of 1988. She has taught students of all ability levels in the seventh grade through college. She has taught at a predominately American Indian school, Red Rock School, in Red Rock, Oklahoma. She developed and taught "Math is Fun" two-week workshops for four-year-olds to thirteen year olds in her home in Stillwater, Oklahoma. From 1962-1964 she served in the Peace Corps in Ecuador. In 1982 she attended the Equity Conference sponsored by the NCTM in Albuquerque, New Mexico. She is past president of Women and Mathematics in Education.

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